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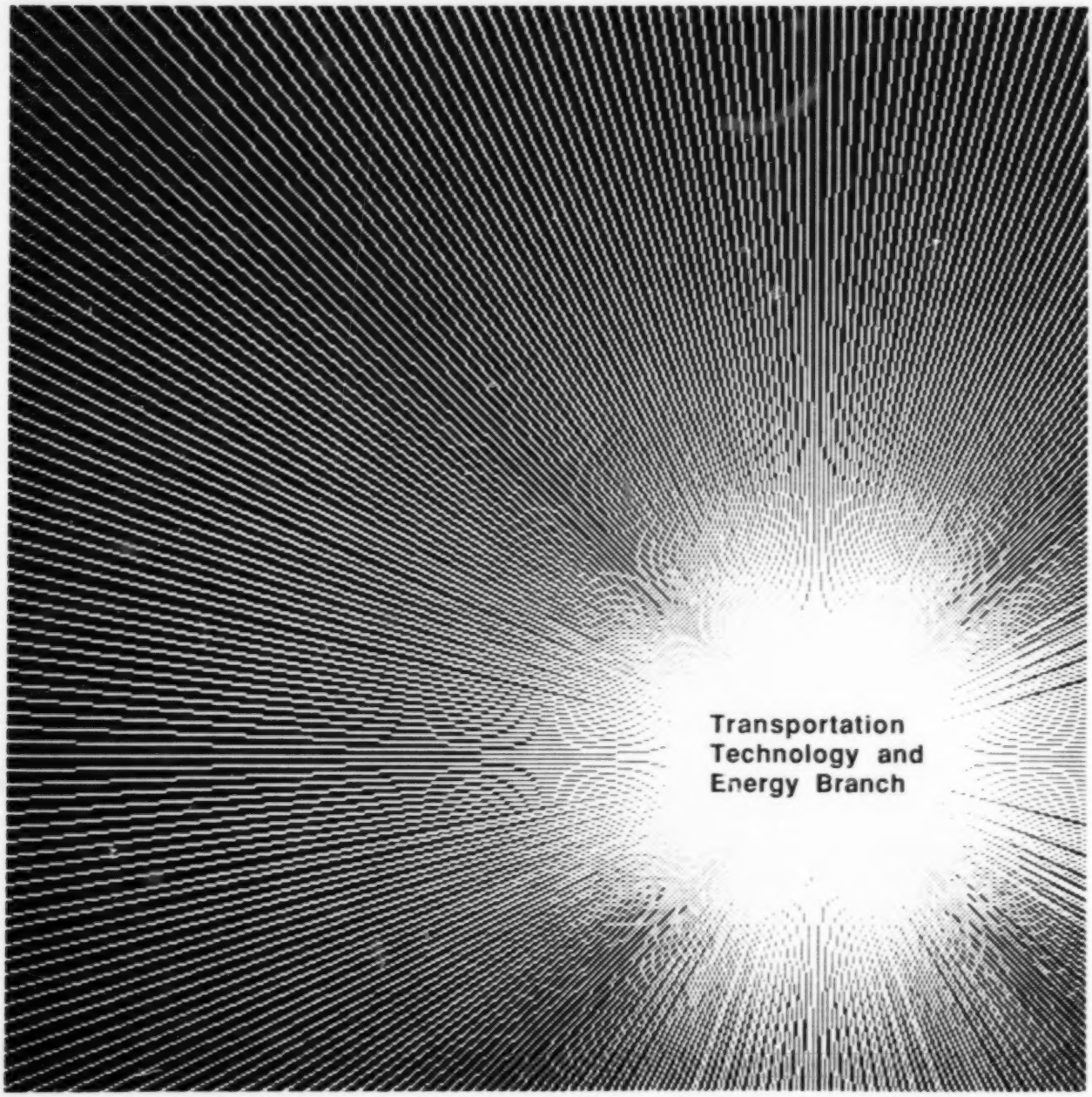

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"Informatics" – Vehicle Location, Communications, Control and Monitoring Systems Under Development in Ontario

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"Informatics" – Vehicle Location, Communications, Control and Monitoring Systems Under Development in Ontario

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This paper was presented at the 1990 RTAC
Annual Conference in St. John's, Newfoundland

Published by:
Transportation Control Technology and Systems Office
Transportation Technology and Energy Branch
Ontario Ministry of Transportation

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Downsview, Ontario
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(416) 235-3466

May 1991

ABSTRACT

Developments in computer, electronics and communications technologies have made possible the development of cost-effective mobile vehicle monitoring and information transmission systems that can have a significant impact on transportation. Systems are under development which allow fleet operators to track their vehicles within cities and across the continent. More sophisticated systems can help guide drivers through unfamiliar neighbourhoods.

This paper provides an overview of the communications, location and control technologies being employed to make these systems a reality. Following a review of technologies, current Ministry of Transportation projects in the areas of Automatic Vehicle Location and Control, and Intelligent Vehicle/Highway Systems are described.

The pressures imposed by growing urban congestion and increasing global competition make the understanding and implementation of systems and technologies to improve transportation safety and efficiency imperative.

1/ INTRODUCTION

We have long accepted that we are living in the information age. We have come to expect to be able to retrieve, process and send information anywhere on the continent, from wherever we happen to be, with a minimum of delay. To serve our needs we have at our disposal telephones, computers, modems, fax machines and electronic mail. These services are made possible by developments in electronics, telecommunications and computing.

Ready access to information was recognized as a vital and cost-effective ingredient of modern business some time ago. Now, the functions of the office are being extended to our homes and automobiles with the availability of cellular phones, portable fax machines, lap top computers and the like.

Once mobile communications, not only voice, but data, became practicable, the transportation industry began to recognize the potential for productivity gains, cost savings and safety improvements that could be achieved from the application of similar technologies on the road. The Ontario Ministry of Transportation (MTO) has initiated and is carrying out a number of projects that take advantage of communications, control and computer technologies in the interest of improved transportation.

Projects under way in the Transportation Control Technology and Systems Office include transit-related Automatic Vehicle Location and Control (AVLC) systems, taxi emergency location systems, the Wide Area Vehicle Monitoring (WAVM) system for satellite-based truck monitoring and dispatch and Intelligent Vehicle/Highway Systems (IVHS) for private vehicle navigation and route guidance. In all these efforts, the goal is to improve transportation safety, mobility and efficiency.

Transit operators, trucking companies, taxi drivers and the general public will benefit from the developments that will result from these activities.

This paper describes these projects and the technologies that make them possible.

2/ INFORMATION TECHNOLOGIES

The primary information-related technologies of interest in transportation include mobile voice and data communications systems, vehicle location and identification systems and computer hardware and software to make systems perform useful functions. The following is a brief introduction to some of these topics.

2.1/ Mobile Communications

The ability to exchange information between fixed locations has, for some time, been a relatively simple task. A combination of the telephone, the computer and the modem

have allowed users easy and virtually unlimited access to any site with a telephone through the public telephone network.

The telephone companies connect their exchanges using microwave, satellite, fibre optic or copper cables.

Communications to and from mobile sites is not quite as simple. For practical purposes, communications takes place in the radio frequency spectrum. Whether the device is a VHF unit, a CB radio, cellular telephone or a satellite base station, communications are achieved by using the radio spectrum. Unlike direct-wired systems which offer virtually unlimited capacity, the available radio spectrum in any location is strictly limited. The effort to develop cost-effective mobile communications schemes revolves around the problem of making efficient use of the available spectrum.

A number of communications schemes have been, or are being, developed to make more efficient use of this scarce resource. One is the cellular telephone network. It allows a limited number of radio frequencies to be used repeatedly at nearby sites by limiting the range of each transmitter. Even with this economic use of spectrum, urban areas are already experiencing cellular telephone congestion. Similar capacity constraints exist in the digital communications field as we...

Improved single side band communications systems and novel developments such as spread spectrum are being introduced to make maximum use of the available channel space. Some standard communications protocols have also been introduced to permit the passing of information in secure, reliable form between a variety of users.

Private communications systems such as those used by fleet operators, transit companies and emergency service providers rely on dedicated communications channels and, for the most part, proprietary protocols. This may mean a central polling system used for automatic monitoring of vehicles or directly addressable two-way radio mobile units in other applications.

For communications to and from remote sites, satellite links provide cost-effective access. Satellite-based communications is now available from mobile units as well. Telesat Mobile Inc. (TMI), a subsidiary of Telesat Canada, recently introduced a two-way digital communications system for use by truckers to communicate with their headquarters. The system gives a trucking company immediate access to any of its vehicles almost anywhere in North America, twenty-four hours a day, and at a reasonable cost.

The challenge is to design communications systems that will be able to keep up with the demand for mobile voice and data communications. With changing lifestyles and increasing competitive pressures, more and more of us will want access to a communications network wherever we happen to be.

2.2/ Automatic Vehicle Identification

A second important element in some transportation-related information systems is the ability to identify vehicles automatically as they go about their normal business.

Automatic vehicle identification (AVI) may be used for automatic toll collection, automatic road pricing, weigh-in-motion (WIM) stations for truck inspection stations and fleet management and contro! purposes.

The latest in AVI is characterized by some form of electronic licence plate or electronic tag mounted on a vehicle. A reader, connected to a central monitoring station, most commonly over leased or dedicated telephone lines, is placed at strategic locations to read the identity of tagged vehicles passing by. In a sense, AVI can be thought of as a short-distance data communications system. In most cases the message is brief and is often restricted to the identification number of the vehicle to which the tag is attached. Communication is generally one way, from the vehicle to the wayside reader. More sophisticated systems will allow additional information to be added to the identification message for transmission by the tag. This could include vehicle status information or driver messages to central dispatch. As well, messages could be sent from central through the reader to the tag and the driver.

A wide range of technologies has been demonstrated, some that permit accurate reading of tags at speeds well over the speed limit and at a range of a few feet up to tens of feet. Although the transmission frequency is most commonly in the radio frequency (RF) range, infrared transmission as well as inductive loops can be employed.

The lowest priced tags, well under $100 each, modulate and reflect RF energy transmitted from wayside antenna/reader units. By using this technique, tags do not need to be directly powered and for short-distance reading need no batteries either. Two of these techniques are surface acoustic wave (SAW) technology and modulated back scatter. A number of demonstrations and some full-scale implementation of these technologies are under way in North America. Ottawa-Carleton Regional Transit Commission (OC Transpo) is about to demonstrate an electronic-tag-based AVLC system, with full-scale implementation planned for next year. Heavy Electronic Licence Plate (HELP), a large-scale demonstration/ development project under way in the western United States and British Columbia uses a Canadian electronic tag system, developed by Vapor Canada, to speed the passage of trucks at weigh stations and other inspection points.

With the development of these technologies and the growth of smart cards, smart tags are being developed. These devices will be able to provide a dynamic link between the driver and a host station and possibly offer very low-cost automatic vehicle location as well as communications capability.

In future, all automobiles may come with electronic tags or licence plates, giving transportation agencies the means to speed passage at toll roads, introduce road user fees or restrict access to certain locations by vehicle I.D. This may become a necessary tool to deal with growing congestion problems in our larger cities. The privacy concerns raised by many will need to be dealt with adequately before such systems can be widely implemented.

2.3/ Automatic Vehicle Location and Navigation

The ability to locate vehicles accurately both within the city and across the country offers opportunities to improve the effectiveness of fleet operations, assist individual drivers to navigate in unknown areas, or to select quicker, shorter or more scenic routes to their destinations. City traffic management agencies will have the tools to optimize the routing of all vehicles in the city in ways which will lead to reduced congestion.

The benefits for fleet management are obvious. The dispatcher can have instantaneous information displayed on a computer-generated map, i.e., the location of any or all vehicles in the fleet. This can speed the response of emergency vehicles and get taxis or trucks to their clients more quickly.

A number of technologies have been and are being developed to provide accurate, reliable and inexpensive vehicle location. Some of these technologies are described below.

2.3.1/ Signpost Systems

Perhaps the simplest and least expensive system currently available relies on short-distance, low-powered radio transmitters, referred to as beacons or signposts, placed by the roadside which transmit their identification to passing vehicles. The vehicle receives the I.D. of the signpost and by the use of a table relating the beacon's I.D. and its location, establishes its own geographic location. Most installed AVLC systems make use of signpost technology because of their proven effectiveness, reliability and reasonable cost. The infrastructure cost of signpost systems can be significant. The in-vehicle elements of the system can be relatively modest.

A further refinement of the system also checks distance travelled by the vehicle through the monitoring of the vehicle's odometer. The signpost/odometer combination can yield location accuracies of a few metres for vehicles such as buses, as long as they travel on predetermined routes and off-route vehicles need not be tracked.

Most vehicles, however, do not operate on fixed routes. In order for signpost systems to be effective in more general applications, a signpost is required on virtually every corner. This is an expensive proposition; therefore, other solutions have been developed for such applications.

2.3.2/ Dead Reckoning Systems

One system requiring no streetside equipment uses the ability of the vehicle to keep track of its location as it moves about. Once its initial position is set, the vehicle keeps track of the distance and direction travelled and calculates its current position. Distance is measured using the vehicle's odometer. Direction is checked either by some form of magnetic compass, the difference of distance travelled by the two front wheels or some form of gyroscope.

In order to improve the longer term accuracy of dead reckoning systems auxiliary correction techniques are normally utilized. This may be through means of map matching, where the calculated position of the vehicle is compared to the road network in the vicinity of the calculated position. When the vehicle turns off the main route its position is compared to known turn-offs and the vehicle's calculated position is updated to the accurately known turn-off nearest its calculated position.

This type of system is still relatively costly and has some inherent limitations, but constant improvements have made dead reckoning systems viable for commercial application. The major advantage of dead reckoning systems is that they do not require the installation of any wayside equipment or supporting infrastructure. This allows for the gradual introduction of the system by the private sector with no public sector participation.

Some Japanese companies are offering such systems in their top-of-the-line vehicles while U.S. automobile companies are participating in demonstration projects to test various concepts.

2.3.3/ Radio Location Systems

The most established wide area location systems rely on the calculation of location obtained through triangulation methods applied to radio signals. Loran-C, widely used for air and marine navigation in North America, consists of a series of synchronized transmitting stations covering most of the continent. A receiver in the vehicle picks up these signals and based on the time of arrival of signals from three Loran transmitters, calculates its position. The accuracy of Loran-C is in the range of 50 to 200 metres.

Loran-C is also being used in land-based applications, forming the location element of the Wide Area Vehicle Monitoring system used for continental truck monitoring, as well as for some newer AVLC systems. Loran-C-based systems allow the receiver of the signal to locate himself. Loran-C is, therefore, well suited to route guidance applications. In order to let a central dispatcher know where it is, the vehicle must still transmit its location to the central dispatcher through some means.

Loran-C transmitters have been in operation for decades and are maintained by federal agencies. The use of the signals is free, but Loran-C receivers are still relatively costly for automobile use, in the order of $2500 each.

In the next few years, a satellite-based location system named Global Positioning System (GPS), and operating on similar principles as Loran-C, will become commercially available. GPS will offer greater accuracy (less than one metre in military applications) and reliability, and possibly lower cost, if the number of users grows as dramatically as anticipated.

Newer schemes also based on radio signal triangulation, which we have dubbed "reverse-Loran," are being developed. In "reverse-Loran" systems it is the vehicle that transmits a signal to wayside receiving stations which calculate the location of the source of the signal. This system allows a central dispatcher to know where his vehicles are without the need for further communication from the vehicle, as is the case with Loran-C or dead-reckoning-based systems. For this reason, "reverse-Loran" systems are ideal for fleet management applications.

In contrast with Loran-C and GPS, reverse-Loran systems have a high up-front infrastructure cost but because of their simplicity, very low receiver costs. As the exact cost of the infrastructure is still to be determined, the cost effectiveness of "reverse-Loran" systems have not been established. The accuracy of these systems is expected to be somewhat better than Loran-C systems.

The most serious shortcoming of radio-based location systems is the interference such systems experience in built-up areas, especially downtown areas with tall structures. This interference can lead to increased location accuracy errors and even total loss of the ability to locate vehicles.

2.3.4/ Applications Software

The last element of a mobile vehicle location/communications system is central software and hardware which integrate and control overall operations. This is where the location function, the communications function and the mapping or dispatching function come together to provide a useful tool for the user.

Much work still needs to take place in developing nationwide standards for communications, mapping and location that will lead to the development of a greater number of practical applications than now exist in mobile vehicle monitoring, location and control.

The next section describes some of the projects under way at the Ministry of Transportation utilizing these technologies to improve transportation safety, efficiency and mobility.

3/ MINISTRY PROJECTS

The Transportation Control Technology and Systems Office and the Traffic and Decision Systems Office of the Transportation Technology and Energy Branch of the Ontario Ministry of Transportation carry out research, development and demonstration projects in the areas of communications, control and automation in various transportation areas. The main areas of interest are Automatic Vehicle Location and Control (AVLC) and Intelligent Vehicle/Highway Systems (IVHS). Table 1 lists current activities in these areas.

The following paragraphs describe in more detail some of the elements of these projects.

3.1/ AVLC Standards for Smaller Properties

Automatic Vehicle Location and Control systems have been around for some time. Over 50 centralized vehicle monitoring and control systems are in operation in North America. The first systems were installed in larger cities, with systems being custom designed for each user. The systems tended to be costly and have required extensive development times and significant user participation. A large majority employ signpost/odometer location systems.

More recently, less complex and smaller systems have been offered by suppliers in standard off-the-shelf packages. The majority of the systems make use of Loran-C for vehicle location and the radio, normally used for voice communications, for transmission of the location data. Many of these systems have some shortcomings in terms of AVLC capabilities offered and exhibit certain weaknesses that could be overcome by more sophisticated application programs.

The Ministry of Transportation, along with seven Ontario municipalities (Windsor, Kitchener, Burlington, Brampton, Mississauga, Sudbury and Peterborough), and the Canadian Urban Transit Association (CUTA) undertook to establish user requirements, examine available systems, and investigate available technologies in an effort to develop a set of AVLC standards. The objective is to define a standard that will lead to the development of a low-cost, functionally complete, and preferably Canadian package that is appropriate to smaller properties.

To date, a set of basic requirements have been agreed upon. Available systems have been reviewed and the investigation of appropriate technologies is nearing completion. The first phase of the project is scheduled to be completed in Fall 1990.

The next phase of the project is to be an implementation of one or more systems based on the developed standard.

3.2/ Wide Area Vehicle Monitoring

The Wide Area Vehicle Monitoring (WAVM) project has resulted in the development and commercial production of a vehicle location and control system similar to an AVLC system, but on a continental scale. The system consists of a Loran-C-based location system and a satellite-based communications system that permits long-distance communication between a truck and its home base.

The system was initially conceived by Mr. Joe Tsai of MTO and was then developed through a committee of Ontario trucking companies and electronics firms. The Ontario Premier's Council Technology Fund contributed about $4.8 million toward research, leading to the development of a final product. Telesat Canada through TMI carried out the work and is providing the service to trucking companies under the product name "Road KIT."

The first official message using the system was sent out by then Premier David Peterson of Ontario on May 1, 1990 going from downtown Toronto to a truck-mounted mobile terminal on Signal Hill in St. John's, Newfoundland.

Current ministry efforts are focused on applying the WAVM technology for other applications. These could include monitoring and communications for remotely located ministry enforcement officers, intercity bus fleets, marine vessels and possibly even individuals such as hikers or anyone operating in remote areas. At the same time, the study is looking at enhancements that may be added to the system such as the provision of real-time traffic, road and weather condition information.

The study phase of this follow-on work is due to be completed by Fall 1990.

3.3/ Taxi Emergency Location System

A number of unfortunate attacks on cab drivers in Toronto in recent years prompted the Metropolitan Toronto Licensing Commission and MTO to begin an investigation of emergency vehicle location systems. The objective of the study was to identify a functional and cost-effective system that would allow a driver in trouble to alert the police or a central monitoring agency to his situation and to automatically provide the police with the identity and location of the driver in distress.

A second objective of the study was to identify other potential users of an emergency location or of a general purpose vehicle location and dispatch system in the city. It was felt that a greater number of users of this service may lead to the identification and development a system that could be offered at a lower cost than the obvious Loran-C alternative.

Interest has been expressed by such groups as the police, ambulance, a number of works departments and some private sector firms.

Investigations to date have identified a number of emerging systems based on the "reverse-Loran" concept. The chief advantage of these systems is the cost advantage they enjoy over similar capability Loran-C systems, if a large enough group of users share the cost of the initial infrastructure.

The study will be completed by September 1990. Discussions are under way that are expected to lead to a demonstration of an emergency location system in Fall 1990. The investigation of the dispatching function will follow, if appropriate.

3.4/ Real-Time Dispatching for Paratransit Operations

The Ministry of Transportation is committed to the support of transportation systems for the disabled. Over 110 municipalities are operating transportation systems for the disabled in the province today.

One serious deficiency in many of these systems is the need for patrons to request pick up one or more days in advance. This makes spontaneous travel by paratransit impossible and places a burden on disabled travellers.

This project was launched with the goal of facilitating last-minute booking through the development of an automated real-time dispatching program. Ideally, the system would allow the call taker to enter a patron's travel request and have the system insert the requested trip into a driver's/vehicle's schedule while the patron remained on the phone. The dispatcher could then confirm the ride immediately and inform the appropriate driver of his new assignment.

The system could possibly be integrated with an AVLC system so that the actual location of the transit vehicle could be entered into the calculation that selected the most appropriate vehicle for the assignment. The system should improve the productivity of paratransit operations by making more optimal use of available resources.

A request for proposals was released in early 1990. Proposals for the development of the booking module have been received. At the time of writing an award had not been made. It is anticipated that one of the proposals will be found acceptable and a contract issued for the development of the real-time dispatching package.

3.5/ Commercial Vehicle Operations and AVI

The efficient movement of commercial vehicles is a priority with fleet operators as well as the ministry. A number of efforts are under way in a number of jurisdictions to reduce the delays faced by truckers at weigh scales, border crossings and other inspection stations.

The Heavy Electronic Licence Plate (HELP) project, sometimes referred to as Crescent, initiated by the State of Arizona and now encompassing several western

American states and British Columbia is the most advanced of these developments. The system involves the installation of electronic tags on trucks, and wayside readers at key points along major interstates. At weigh scales, weigh-in-motion (WIM) scales may also be provided. The purpose of the system is to automatically clear, without the need to stop, those trucks that have previously been cleared at nearby stations or those that do not exceed axle weight limits.

Similar efforts have recently been initiated by the State of Kentucky to implement an AVI system along I-75, the main interstate connecting Michigan to Florida. Again the purpose is to minimize delays to truckers and to streamline the work of state inspection agencies.

Separate informal technical discussions have been held by the Ministry of Transportation with Canadian federal agencies, the Province of Quebec and the State of Michigan to try to establish the technical parameters of a potential Automatic Vehicle Identification (AVI) system and to discuss the need for international standards for commercial vehicle AVI systems.

This effort is just beginning in Ontario. Significant developments are expected to take place, however, in the next year or two.

3.6/ Real-Time Traffic Data Collection

Urban congestion has appeared at the top of the list of things city dwellers dislike most about living in large cities. The continuing growth in vehicle travel has led to increased travel times, growing pollution and greater driver frustration. Clearly, we can no longer build our way out of congestion and, therefore, other solutions must be found. The move to greater use of transit along with efforts to bring sound urban planning principles to bear on city growth, are going to have to play a greater role in dealing with congestion problems.

Technology can also provide some assistance. Under the umbrella of Intelligent Vehicle/Highway Systems (IVHS), efforts are being made to improve traffic management systems such as computerized traffic control systems and freeway traffic management systems. Somewhat further away in time are systems that will direct drivers to less congested routes in an effort to either minimize overall system congestion and delay or to minimize the driver's travel time.

The key to optimizing the movement of vehicles through individual driver direction or freeway and signal timing control is information on up-to-the-minute road and driving conditions. Possession of such real-time traffic data opens up many possibilities to develop optimal routing, signal timing or diversion plans. The information could also be used to provide the public with up-to-date information on driving conditions in the city.

To this end, a project has been initiated by the ministry in Toronto with participation by the Toronto Transit Commission and the Metropolitan Toronto Transportation Department. The study will look into the feasibility of collecting detailed travel speed information, in real time, on major routes within the city and Highway 401, the main east-west highway traversing the city. The information on freeway movement will come from the recently completed Highway 401 Freeway Traffic Management System. A 15 km section of the twelve-lane highway is equipped with loop detectors, TV cameras, communications equipment and changeable message signs.

Information on arterial travel will have to come from inductive loop detectors and possibly from the Communications Information Systems (CIS) being installed by the Toronto Transit Commission to monitor the movement of over 1800 buses and streetcars in the city. The CIS provides vehicle location information that is updated approximately once every fifteen seconds. It is expected that this data can be used to generate individual block travel times after correction for bus stop dwell times and associated delays.

The feasibility study will determine what information is required to make possible the generation of useful, real-time traffic condition information. Then, the means to collect and generate this information will be examined. If the study concludes that a system of this type is feasible, a demonstration of the data collection and processing system will be staged.

3.7/ Real-Time Route Guidance

As described above, one way to attack the problem of traffic congestion is by helping drivers optimize their routes and avoid areas of congestion. Systems are already available to help drivers navigate in strange surroundings using on-board electronic maps displaying their location as they travel.

What these navigation systems lack at the moment is travel time or traffic congestion information. With this information, drivers could look at traffic conditions in their vicinity and choose the least congested route available to them. Even better would be an in-vehicle system that automatically calculates the best route from the information provided by the driver and the traffic information system. Drivers would key in their destinations, and the traffic system would broadcast traffic conditions describing the metropolitan area. The driver's starting location could either be keyed in by the driver or automatically made available by the vehicle's location system.

Professor Van Aerde of Queen's University, with funding assistance from the ministry, has developed an efficient routing algorithm for just such a task. The other elements of the system, including the traffic information broadcasting system and the in-vehicle hardware to receive the data and process the information to generate routing instructions, can be developed. The most difficult aspect of the system is the collection and

processing of reliable, timely and consistent traffic data, which the Real-Time Traffic Data Collection project (Section 3.6 above) is designed to provide.

The goal of developing "intelligent" vehicles, which will not only respond to driver commands but suggest how best to get to one's destination, is now within sight. Before the end of the decade, the first generation of these systems will be as common as the car radio is today.

The present efforts at the Ministry of Transportation and Queen's University are early steps in this direction.

4/ SUMMARY AND CONCLUSIONS

The period of massive growth in road infrastructure to meet the capacity demands of an increasingly mobile population passed some time ago. We must rely on other means to ensure that a high standard of mobility and modal choices remain for our citizens and industries. Advances in technology, particularly in the areas of computers and communications, is most timely to assist us in this endeavour.

Novel combinations of vehicle identification, location, communication and control techniques makes the development and mass marketing of products to assist both the general public and transportation companies and agencies inevitable.

It is essential for those in decision-making positions in transportation agencies and transportation firms to have an appreciation of these opportunities and a clear understanding of the technologies that make them possible.

For those responsible for developing, funding or using these systems, having a grasp of basics is just the beginning. Those in positions of influence and responsibility need to address the issues of standardization, continental system integration and global competitiveness when considering the application of advanced transportation technologies.

Transportation agencies in the United States, Europe and Japan have come to appreciate the importance of advanced transportation information systems for national security, national competitiveness and industrial leadership reasons. Major efforts are under way at the highest levels to define long-term research, development and implementation programs under the umbrella of IVHS.

Canada too has taken steps in this direction, firstly by participating in the American definition efforts and secondly by taking steps to identify a similar Canadian program. Canada's expertise in communications and information technologies and active programs in Freeway Traffic Management, Wide Area Vehicle Monitoring and Automatic Vehicle Location and Control puts us in an excellent position to play a major

role in the development and commercialization of transportation-related information systems.

In Fall 1989, an international conference was held in Toronto, led by the Ministry of Transportation, focusing on Vehicle Navigation and Information Systems (VNIS). Since the conference, a round table of federal and provincial representatives have been meeting to help define Canada's role in the IVHS field. One of the first activities of the round table will be the organization of regional seminars to bring the message of, and developments in IVHS to the attention of a wider group of industry, government and university representatives.

Government and industry can then move forward to exploit the opportunities offered by Canadian know-how in the field of informatics and work with American and possibly European and Japanese groups in defining, developing and implementing systems that will benefit all of us.

Table 1/ Current Informatics-Related MTO Research Projects

AUTOMATIC VEHICLE LOCATION AND CONTROL (AVLC) PROJECTS

1/ AVLC Standards for Smaller Properties
Establish user requirements, evaluate available systems and technologies and carry out demonstrations of the identified standard system.

2/ Wide Area Vehicle Monitoring (WAVM)
Develop satellite- and Loran-C-based vehicle location and communications system for the trucking industry. Examine other users and system enhancements.

3/ Taxi Emergency Location System
Evaluate and demonstrate urban vehicle location systems for taxis and other vehicles.

4/ Real-Time Dispatching for Paratransit Operations
Develop a software package for automatic dispatching for Transportation for Disabled systems.

INTELLIGENT VEHICLE/HIGHWAY SYSTEMS PROJECTS

5/ Commercial Vehicle Operations and AVI
Identify needs and investigate alternative AVI systems to assist with truck clearing at weigh stations and border crossings. Participate in AVI projects in the U.S.A. and Canada.

6/ Real-Time Traffic Data Collection
Examine the feasibility of developing a system to collect, process and distribute real-time traffic data in Metropolitan Toronto. Follow by possible demonstration.

7/ Real-Time Route Guidance
Develop route guidance algorithm and supporting hardware and communications system to improve mobility in the city.